

What is claimed is:

1. A method of charging batteries in a system of batteries, the method comprising:

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producing a set of state of charge signals indicative of the states of charge of each battery in said system;

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successively identifying, from the state of charge signals, a most discharged battery in said system; and

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applying a charging current to said most discharged battery for a at least part of a first period of time less than a period of time required to fully charge said most discharged battery before identifying a succeeding most discharged battery in said system.

2. The method of claim 1 wherein producing said set of state of charge signals comprises measuring voltages of the batteries in the system.

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3. The method of claim 2 further comprising isolating a power supply from a battery while said voltage of said battery is being measured.

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4. The method of claim 3 wherein isolating said power supply comprises providing a signal to a controllable power supply to de-energize said controllable power supply .

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5. The method of claim 4 wherein producing said set of state of charge signals comprises successively connecting said power supply bus to each battery in said system and storing voltage measurements of the batteries as said set of state of charge signals.

- 5 **6.** The method of claim **5** wherein identifying comprises determining which battery of said system is associated with a lowest voltage measurement and associating with said battery associated with said lowest voltage measurement an identifier identifying it as said most discharged battery.
- 10 **7.** The method of claim **1** wherein said first period of time is such that at least a current state of charge of said most discharged battery is maintained over time.
- 8.** The method of claim **1** wherein said first period of time is such that at least a current state of charge of said most discharged battery is increased over time.
- 15 **9.** The method of claim **1** wherein said first period of time is long enough to avoid interference in a load connected to said most discharged battery.
- 20 **10.** The method of claim **1** wherein said first period of time is between about **1** and about **30** seconds.
- 11.** The method of claim **1** further comprising selecting said first period of time in response to a chemical type of said most discharged battery.
- 25 **12.** The method of claim **1** further comprising receiving user input defining said first period of time.
- 13.** The method of claim **12** further comprising storing said user input as stored user input.
- 30 **14.** The method of claim **13** further comprising recalling said stored user input to determine said first period of time .

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15. The method of claim 1 wherein applying said charging current to said most discharged battery comprises connecting a power supply to said most discharged battery for said first period of time.
16. The method of claim 15 further comprising controlling said power supply to produce said charging current according to a charge profile associated with said most discharged battery.
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17. The method of claim 15 wherein applying said charging current comprises activating a first timer for said first period of time, said power supply being connected to said most discharged battery while said first timer is activated.
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18. The method of claim 17 further comprising disconnecting said most discharged battery from said power supply during said first period of time if said charge current meets a first criterion during said first period of time.
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19. The method of claim 18 wherein said charge current meets said first criterion when said charge current is less than a threshold value after a minimum period of time within said first period of time.
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20. The method of claim 19 wherein said minimum period of time is long enough to avoid interference in a load connected to said most discharged battery.
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21. The method of claim 19 wherein said minimum period of time is greater than about 1 second.
22. The method of claim 21 wherein said minimum period of time is less than about 5 seconds.

23. The method of claim **22** wherein said first period of time is between about **1** second and about **30** seconds.

24. The method of claim **15** wherein connecting said power supply to said most discharged battery comprises causing a current distributor to connect said most discharged battery to at least one pole of said power supply.

25. The method of claim **24** wherein causing said current distributor to connect said most discharged battery to at least one pole of said power supply comprises activating a switching circuit connected between said at least one pole of said power supply and said most discharged battery.

26. The method of claim **25** wherein activating a switching circuit comprises turning on a semiconductor switch connected between said at least one pole of said power supply and said most discharged battery.

27. The method of claim **15** wherein connecting said power supply to said most discharged battery comprises causing a current distributor to connect said most discharged battery to respective poles of said power supply.

28. The method of claim **27** wherein connecting said power supply to said most discharged battery comprises activating first and second switching circuits connected to respective poles of said power supply and to respective poles of said most discharged battery.

29. The method of claim **28** wherein activating said first and second switching circuits comprises turning on first and second semiconductor

switches associated with said first and second switching circuits respectively where said first semiconductor switch is connected between a first pole of said power supply and a first pole of said most discharged battery and wherein said second semiconductor switch is connected between a second pole of said power supply and a second pole of said most discharged battery.

30. The method of claim **1** further comprising maintaining at least part of said charging current to said most discharged battery until the state of charge of said most discharged battery is within a range of the state of charge of a battery in said system having the next higher state of charge relative to the state of charge of said most discharged battery as determined from a last produced set of state of charge signals, before producing a succeeding set of state of charge signals.

31. The method of claim **1** wherein said batteries are connected to respective battery ports of a current distributor having a plurality of battery ports and wherein said method further comprises determining which of said battery ports has a battery connected thereto.

32. The method of claim **31** wherein determining which of said battery ports has a battery connected thereto is successively performed less frequently than a frequency at which said set of state of charge signals is produced.

33. The method of claim **32** wherein said method comprises setting a port detection timer after determining which of said battery ports has a battery connected thereto and re-determining which of said ports has a battery connected thereto when said port detection timer has timed-out.

34. The method of claim **31** wherein determining which of said battery ports has a battery connected thereto comprises scanning said battery ports.

5 **35.** The method of claim **34** wherein scanning said battery ports comprises successively activating each of said battery ports and, while a battery port is activated, permitting a current to be drawn from said battery port.

10 **36.** The method of claim **35** further comprising determining whether said current to be drawn from said battery port meets a test criterion and identifying said battery port as having a battery connected thereto when said test criterion is met.

15 **37.** The method of claim **36** wherein said test criterion is met when said current drawn from said battery port exceeds a threshold current value after a test period of time.

20 **38.** An apparatus for charging batteries in a system of batteries, the apparatus comprising:

a state of charge signal generator operable to produce state of charge signals indicative of the states of charge of each battery in said system;

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a power supply operable to produce a charging current;

a current distributor operable to selectively connect each battery in said system to said power supply in response to a control signal;

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a controller configured to:

communicate with said state of charge signal generator to successively produce a set of said state of charge signals indicative of the states of charge of each battery in said system;

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successively identify, from said set of state of charge signals, a most discharged battery in said system; and

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produce said control signal to cause said current distributor to selectively connect said most discharged battery to said power supply such that said most discharged battery receives said charging current from said power supply for at least part of a first period of time less than a period of time required to fully charge said most discharged battery, before identifying a succeeding most discharged battery in said system.

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39. The apparatus of claim **38** wherein said state of charge generator comprises a voltage sensor operable to measure voltages of the batteries in the system.

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40. The apparatus of claim **39** wherein said power supply is operable to be isolated from a battery of said system while said voltage of said battery is being measured.

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41. The apparatus of claim **40** wherein said power supply is controllable and wherein said controller is configured to provide a signal to said power supply to de-energize said power supply.

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42. The apparatus of claim **41** wherein said state of charge signal generator includes said controller, said controller being configured to

successively connect said power supply to each battery in said system and to store voltage measurements of the batteries as said set of state of charge signals.

- 5 **43.** The apparatus of claim **42** wherein said controller is configured to determine which battery of said system is associated with a lowest voltage measurement and to associate with said which battery an identifier identifying it as said most discharged battery.
- 10 **44.** The apparatus of claim **38** wherein said first period of time is selected such that at least a current state of charge of said most discharged battery is maintained over time.
- 15 **45.** The apparatus of claim **38** wherein said first period of time is selected such that at least a current state of charge of said most discharged battery is increased over time.
- 20 **46.** The apparatus of claim **38** wherein said first period of time is selected to avoid interference in a load connected to said most discharged battery.
- 25 **47.** The apparatus of claim **44** wherein said first period of time is selected to avoid interference in a load connected to said most discharged battery.
- 30 **48.** The apparatus of claim **38** wherein said first period of time is between about **1** second and about **30** seconds.
- 49.** The apparatus of claim **38** wherein said first period of time is selected in response to the chemical type of said most discharged battery.

50. The apparatus of claim **38** further comprising a user input port operable to receive user input defining said first period of time.
- 5 51. The apparatus of claim **50** wherein said controller is configured to store said user input as stored user input.
52. The apparatus of claim **51** wherein said controller is configured to recall.
- 10 53. The apparatus of claim **38** wherein said controller is configured to control said power supply to cause it to produce said charging current according to a charge profile associated with said most discharged battery.
- 15 54. The apparatus of claim **38** wherein said controller is configured to activate a first timer for said first period of time, and cause said current distributor to be operated such that said power supply is connected to said most discharged battery while said first timer is activated.
- 20 55. The apparatus of claim **54** wherein said controller is configured to control said current distributor to disconnect said most discharged battery from said power supply during said first period of time if said charge current meets a first criterion during said first period of time.
- 25 56. The apparatus of claim **55** wherein said controller is configured to determine said charge current meets said first criterion when said charge current is less than a threshold value after a minimum period of time within said first period of time.
- 30 57. The method of claim **56** wherein said minimum period of time is such as to avoid interference in a load connected to said most discharged battery.

58. The apparatus of claim **56** wherein said minimum period of time is greater than about **1** second.

5 **59.** The apparatus of claim **58** wherein said minimum period of time is less than about **5** seconds.

60. The apparatus of claim **58** wherein said first period of time is about **20** seconds.

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61. The apparatus of claim **53** wherein said power supply includes first and second poles and wherein said current distributor is operable to connect said most discharged battery to said first and second poles of said power supply.

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62. The apparatus of claim **61** wherein said current distributor comprises a switching circuit operable to be connected between said at least one of said first and second poles and said most discharged battery.

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63. The apparatus of claim **62** wherein said switching circuit comprises a semiconductor switch operable to be connected between said at least one of said first and second poles and said most discharged battery.

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64. The apparatus of claim **53** wherein said power supply has first and second poles and wherein said current distributor is operable to separately connect said first and second poles to respective poles of said most discharged battery.

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65. The apparatus of claim **64** wherein said current distributor comprises first and second switching circuits operable to be connected to said first and second poles respectively of said power supply and to respective poles of said most discharged battery.

- 5 **66.** The apparatus of claim **65** wherein said first and second switching circuits comprise corresponding first and second semiconductor switches, said first semiconductor switch being operable to be connected between said first pole of said power supply and a first pole of said most discharged battery and said second semiconductor switch being operable to be connected between a second pole of said power supply and a second pole of said most discharged battery.
- 10 **67.** The apparatus of claim **38** wherein said controller is configured to maintain at least part of said charging current to said most discharged battery until the state of charge of said most discharged battery is within a range of the state of charge of a battery in said system having the next higher state of charge relative to the state of charge of said most discharged battery as determined from a last produced set of state of charge signals, before producing a succeeding set of state of charge signals.
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- 20 **68.** The apparatus of claim **38** wherein said current distributor has a plurality of battery ports and wherein said controller is configured to determine which of said battery ports has a battery connected thereto.
- 25 **69.** The apparatus of claim **68** wherein said controller is configured to successively determine which of said battery ports has a battery connected thereto at a frequency less than a frequency at which said set of state of charge signals is produced.
- 30 **70.** The apparatus of claim **69** wherein said controller is configured to implement and set a port detection timer after determining which of said battery ports has a battery connected thereto and to re-determine which of said ports has a battery connected thereto when said port detection timer has timed-out.

71. The apparatus of claim 68 wherein said controller is configured to scan said battery ports to determine which of said battery ports has a battery connected thereto.

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72. The apparatus of claim 71 wherein said controller is configured to scan said battery ports by causing each of said battery ports to be successively activated and, while a battery port is activated, causing a current to be drawn from said battery port.

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73. The apparatus of claim 72 wherein said controller is configured to determine whether said current drawn from said battery port meets a test criterion and to identify said battery port as having a battery connected thereto when said test criterion is met.

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74. The apparatus of claim 73 wherein said controller is configured to determine that said current drawn from said battery port meets said test criterion when said current drawn from said battery port exceeds a test current value after a threshold period of time.

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75. An apparatus for charging batteries in a system of batteries, the apparatus comprising:

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means for producing a set of state of charge signals indicative of the states of charge of each battery in said system;

means for successively identifying, from said state of charge signals, a most discharged battery in said system; and

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means for applying a charging current to said most discharged battery for at least part of a first period of time less than a period of time required to fully charge said most discharged battery

before identifying a succeeding most discharged battery in said system.

5 **76.** In a charger for charging batteries in a system of batteries, where the
charger comprises a state of charge signal generator operable to
produce state of charge signals indicative of the states of charge of
each battery in said system, a controllable power supply operable to
produce a charging current, a current distributor operable to selectively
10 connect each battery in said system to said power supply in response
to a control signal, and a controller operable to communicate with said
state of charge signal generator, said power supply and said current
distributor, a method of operating the controller, the method
comprising:

15 causing said controller to communicate with said state of charge
signal generator to produce a set of said state of charge signals
indicative of the states of charge of each battery in said system;

20 causing said controller to successively identify, from said state
of charge signals, a most discharged battery in said system; and

25 causing said controller to produce said control signal to cause
said current distributor to selectively connect said most
discharged battery to said power supply such that said most
discharged battery receives said charging current from said
power supply for at least part of a period of time less than a
period of time required to fully charge said most discharged
battery, before causing said controller to identify a succeeding
most discharged battery in said system.

30 **77.** A computer readable medium comprising codes for directing a
controller in a charger for charging batteries in a system of batteries,

where the charger comprises a state of charge signal generator operable to produce state of charge signals indicative of the states of charge of each battery in said system, a controllable power supply operable to produce a charging current and a current distributor operable to selectively connect each battery in said system to said power supply in response to a control signal, and wherein the controller is operable to communicate with said state of charge signal generator, said power supply and said current distributor, the computer readable medium comprising codes readable by the controller for directing the controller to:

communicate with said state of charge signal generator to successively produce a set of said state of charge signals indicative of the states of charge of each battery in said system;

successively identify, from said state of charge signals, a most discharged battery in said system; and

produce said control signal to cause said current distributor to selectively connect said most discharged battery to said power supply such that said most discharged battery receives charging current from said power supply for at least part of a period of time less than a period of time required to fully charge said most discharged battery, before causing said controller to identify a succeeding most discharged battery in said system.

78. A method of charging a plurality of batteries, the method comprising charging said batteries according to a dynamic charging sequence in which batteries are added into the charging sequence in order of increasing state of charge as batteries or battery banks already in the charging sequence are charged to exceed the state of charge of a battery or battery bank having the

next higher state of charge relative to the state of charge of the batteries already in the charging sequence.